transmit them, their host range, and varietal reactions. Until more detailed knowledge is available there is little basis for suggesting a sound program of control.

Dr. Magie, in the North American Gladiolus Council Bulletin No. 20, December 1949, suggested the value of certifying planting stock of gladiolus, comparable to the program of certifying white potatoes. The stocks, he wrote, might be "produced in parts of the country where disease spread is naturally light or absent." He was concerned mainly with fusarium rot control, but he also mentioned virus control. Such a program would be good if it could be put into practice. But no one knows now which areas are favored by light spread of gladiolus viruses; more research is necessary before the gladiolus industry can follow the path of the potato industry; and the number of gladiolus varieties in the trade, already enormous, is continually augmented by the new productions of hundreds of amateur breeders. Therefore we find less interest in protecting the present commercial varieties than in developing new sorts. Of course the situation would improve if breeders of gladiolus would take all possible care to avoid exposing their seedlings to sources of infection so that only disease-free new varieties might enter the trade.

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Blights of Lilies and Tulips

C. J. Gould

Whether one grows tulips or lilies for fun or for profit—in Brooklyn, Keokuk, or Seattle; in the garden, field, or greenhouse—he probably has more grief from botrytis blights than from any other cause.

The blights, or "fire" as they are sometimes called, are world-wide in distribution and most prevalent in cool, moist areas. They are caused by similar, but distinct, fungi. Most common on tulips is *Botrytis tulipae*. Most common on lilies is *Botrytis elliptica*.

Tulip blight begins with a diseased bulb or with contaminated soil in which the fungus is living on old remains of the tulip plant. As the young tulip shoot pushes through the ground, it becomes infected if it comes in contact with the fungus and may be changed into a distorted, grayish-brown body covered with powdery masses of spores. Sometimes only part of a leaf is diseased. Often the entire shoot is affected. Soon the leaves of the nearby tulip plants become spotted with small, circular, yellow or brown dots. Many of the spots remain small and dry up, but others, (especially if the weather is cool and moist) enlarge rapidly. Their color becomes a grayish brown or brown, with a dark water-soaked margin. Powdery masses of spores often form in the center. These, when blown to other plants, initiate more spots, which may become visible within 24 hours.

Large spots near the leaf base often

cause the leaf to break. Several spots may fuse and decay a leaf completely. Spots on stems are similar and may also cause the stems to break. Flowers are very susceptible and often are made unsalable by white or brown spots covered with spores. Not even the bulb escapes. On its outer fleshy scale the fungus may produce sunken, yellow or brown craters. In them, on the outer bulb husk, and on spots on the upper plant parts, small, hard, black circular masses of the fungus may develop. Such black bodies, the sclerotia, have a function somewhat similar to seeds in that they enable the fungus to live over winter, either on the bulb or on dead tulip parts. Then, when infection from the sclerotia occurs in the spring, the cycle is continued by the spores.

The disease probably occurs wherever tulips are grown, but it is most serious when conditions are cool and moist. Consequently it is prevalent in the Netherlands, southwestern England, and the Pacific Northwest.

Local conditions, however, are important: In western Washington, for example, the disease is more serious in the valleys near Puyallup than it is 90 miles to the north near Mount Vernon, where the plants are exposed to a more or less constant wind from Puget Sound.

The method of planting tulips commercially in beds about 3 feet wide, as practiced in Holland and some parts of the United States, is more conducive to botrytis blight than is the row system used in the Pacific Northwest. Not only is the relative humidity higher in the beds, but there is also a greater opportunity for infection. Likewise the disease is often found in gardens in massed plantings or on plants in shaded places.

Most, if not all, tulip varieties are susceptible, but there is some variation. Among varieties that are very susceptible are the popular William Copland, William Pitt, and Bartigon. Baronne de la Tonnaye is supposed to be resistant. This species of *Botrytis* can also attack bulbous plants other than tulips under certain conditions according to tests by Neil A. MacLean at Washington State College. Other species of *Botrytis*, including *B. cinerea*, can sometimes attack tulips.

Although *B. tulipae* can attack healthy leaves, its entrance is facilitated by injuries from frost, hail, and equipment. The Dutch have tried to reduce frost injury by treating the bulbs to delay growth in the spring until the danger is partly over. This artificial retarding is accomplished by storing the bulbs at approximately 70° F. and delaying planting until October or November.

Much can be done to control the disease in commercial fields and home gardens by proper cultural practices: Digging every year; not replanting tulips in the same location for at least 3 years; planting so as to provide good air circulation and low humidity by proper selection of site, proper spacing, and thorough weeding; removing promptly and destroying diseased shoots, old and infected flowers, and dead plant remains; and planting only healthy bulbs.

Since the original infections arise from diseased bulbs that escape detection, it would seem logical to treat them with a fungicide in order to destroy the fungus. Many treatments have been tested and a few have been recommended, such as Uspulun and Aretan, in Europe. Such treatments have not met with general success, however. Either they injured the bulbs or failed to control the disease adequately.

Early attempts to prevent plants from becoming diseased by using fungicidal sprays were likewise not very successful. Although copper-containing compounds such as bordeaux mixture were found capable of controlling the fungus, they often caused considerable injury to the leaves and flowers. However, in New York in 1940 L. W. Nielson and C. E. Williamson found that silver nitrate sprays compared favorably with the 1.5-4.5-50 bordeaux mixture in fungicidal action. One spray, containing silver nitrate, manganese sulfate, and hydrated lime was adopted by bulb growers on Long Island.

Meanwhile tests in 1938 in the Netherlands had shown promising results with thiram, one of the new organic-sulfur compounds. I tested it and related sulfur compounds in comparison with silver and copper fungicides at the Western Washington Agricultural Experiment Station beginning in 1942. Then and later the best results were had with ferbam, another organic sulfur compound. Large-scale tests by growers in 1943 corroborated the experimental trials. Afterwards it came into general use in the Pacific Northwest and the Netherlands.

Four applications of ferbam are usually enough in the Northwest, beginning when the shoots are 2 to 4 inches tall and continuing at 7- to 10-day intervals. The spraying must be accompanied by the prompt removal of infected plants as soon as detected. By combining the proper cultural practices and a spraying program, the disease can now be conquered.

Botrytis blight of lilies, like tulip blight, is an old enemy. Apparently distributed all over the world, it is infectious to all species and varieties of lilies. Some species, such as *Lilium candidum*, the Madonna lily, may be killed to the ground if conditions favor development of the blight. The fungus most often responsible is *Botrytis elliptica*, but a few other species of *Botrytis*, including the common *B. cinerea*, can parasitize lilies under certain conditions.

Although *B. elliptica* may occasionally rot the growing point of small plants, the usual visible symptom is a leaf spotting. The spots at first are small, circular or elongated, and brown or reddish-brown, with a yellowish or water-soaked margin. Under cool, moist conditions they may enlarge, becoming paler in color, and sometimes completely rotting the leaf. The fungus may attack stems near the soil level and so injure them that the foliage above turns yellow.

Spots on the flowers usually are brown and in cool, moist weather rapidly convert the flowers into wet, slimy masses covered with powdery layers of spores. In warm, dry weather the spots on leaves and flowers stop enlarging and dry up. With ample moisture and an optimum temperature near 60° F., however, a new spot may develop within 24 hours and new spores within a few days thereafter. Given suitable moisture and temperature conditions, the cycle may repeat itself every few days throughout the growing season. Meanwhile, hardened masses of the fungus are forming in the diseased portions. These masses, the sclerotia, are first white and later black. They may be rounded, elliptical or irregular, and one-thirty-second to one-quarter inch in size. Under favorable conditions the sclerotia germinate the following spring to produce spores.

The fungus overwinters in at least three ways: It can survive in the form of sclerotia. It can live saprophytically in lily debris. It can survive in the basal rosettes of leaves of such lilies as the Madonna lily. It may also possibly survive in nonlily hosts, since Neil A. MacLean of the State College of Washington discovered that some other plants are susceptible to the fungus. He demonstrated also that the fungus sometimes could rot lily bulbs. That implies another method of overwintering of the fungus, although it apparently seldom happens in nature.

Moisture is necessary for the germination of spores of the fungus and also for their formation. A saturated atmosphere is required for formation at 80° F., although at lower temperatures a slightly lower humidity permits development. Under favorable conditions spores may form on infected spots and become mature within 9 hours. Germination can only occur in a film of water. Under favorable conditions the fungus can produce visible water-soaked areas within 10 hours after lodging on a leaf. Although the optimum temperature for infection is near 60°, once the fungus has entered the plant it then grows best at 70°.

Since a high relative humidity is necessary for both spore formation and germination, it is evident that areas of high rainfall or heavy dews should be favorable for the fungus, provided the temperature is cool enough. Thus the heavy rainfall of the west coast and Gulf States accounts for the severity in those places; according to C. E. F. Guterman, the heavy dews explain the prevalence of the disease in Long Island and Bermuda. The disease is also common in greenhouses, especially during periods of cloudy, wet weather in the fall before heat is turned on.

Although all lilies are apparently susceptible to botrytis blight to a certain extent, they vary in susceptibility. The very susceptible species include *L. candidum*, *L. chalcedonicum*, *L. humboldtii*, and *L. testaceum*. *L. speciosum* is somewhat less susceptible. Among the resistant types are *L. giganteum* and *L. willmottiae*. The Easter lily, *Lilium longiflorum*, is classed as susceptible, but F. P. McWhorter has pointed out that the variety Ace is more resistant than the more commonly grown Croft.

Control measures are largely a matter of changing the factors that favor the survival of the fungus. Although not much can be done about rain and dew, it is possible to lower the humidity by planting lilies in locations with good air circulation, avoiding low or shaded spots, avoiding massed plantings, and preventing weed growth.

One should also avoid cultivating or otherwise disturbing the plants when they are wet with dew or rain. In greenhouses the judicious use of heat and ventilation together with proper watering should help keep the humidity down to a point unfavorable for the fungus.

Protection with fungicides is usually a necessary addition to good cultural practice, especially in commercial plantings and in home gardens on such very susceptible types as the Madonna lily. Bordeaux mixture, with a wetting and sticking agent, gives good results if it is applied before the disease has become extremely serious. A weekly application is necessary in wet weather, but otherwise a spray every other week is usually sufficient.

Many other types of copper sprays and dusts would likely serve as well as bordeaux mixture if proper coverage is obtained. Ferbam has given good control of the botrytis blight of tulips, but it failed to give more than fair control of the lily blight in tests I have conducted in Washington.

Also necessary is sanitation—the elimination of the sources of spores. The diseased leaves and old flowers should be removed in home gardens. Many growers also have found it desirable to remove the flowers from commercial plantings. If all debris is destroyed at the end of the growing season, a major source of infection is eliminated. It has also been suggested that the basal rosette leaves of *L. candidum* be cut off just below the ground line in midwinter. This variety should be separated from less susceptible ones and all types should be replanted in a different location whenever dug.

Control measures therefore for lily blight are nothing more than the application of general good growing procedures, supplemented with fungicidal sprays when necessary.

One of the most popular lilies is *Lilium longiflorum*, the Easter lily. Of the several varieties, the one usually seen in florists' shops at Easter is the Croft, which was developed in the West Coast States, where the center of production still exists. At the time of its introduction and for many years thereafter Crofts were grown in greenhouses without much trouble from diseases. Then a puzzling leaf spotting or scorching began to be reported occasionally in different parts of the country. Finally, in the 1947–1948 forcing season it became prevalent on Croft lilies in many greenhouses in the East, and since has become increasingly serious in many sections.

The condition has been called leaf spot, leaf burn, tip burn, and leaf scorch. The last is the generally accepted term. The symptom usually seen begins near the end of the leaf as a semicircular spot, which may enlarge until the entire tip is affected. Such spots develop most often on the upper part of the plant and after the flower buds appear. Usually only a few leaves are affected, but in severe cases nearly all may be spotted. The condition is usually most severe on plants with light-colored leaves or on those forced rapidly. It appears more frequently following bright sunny days than cloudy ones. Such spots so disfigure the plants that the leaves may have to be trimmed with scissors before they can be marketed.

Although fumigation with nicotine for insect control had produced somewhat similar injury, leaf scorch sometimes appeared where nicotine had never been used. The disorder also resembled botrytis blight in many respects, but the usual blight control measures were ineffective. It differed from the blight in that the spots regularly occurred on the margins of the leaves, usually an inch or two from the tip, and never on the flowers; the botrytis spots were scattered on the leaves and numerous on the blossoms. The possibility that it was caused by a fungus was discarded when research workers demonstrated that the fungus could not be detected in typical scorched spots. So it appeared to be a physiological problem, and investigations since have proceeded on that basis.

Neil W. Stuart at the Plant Industry Station at Beltsville, Md., noticed in 1945 that lilies fertilized with nitrogen during forcing showed fewer scorched leaves than unfertilized plants. He followed the observation with experiments in the greenhouse, using various types of fertilizers. He found that under his conditions nitrogen fertilizer alone reduced the leaf burning, but the inclusion of phosphorus and potash in the mixture counteracted the beneficial effect of the nitrogen. He reported the experiments in 1949 with the statement that "more than one factor is concerned in the leaf-spotting problem."

The soundness of the statement has been emphasized by later work. The beneficial effect of nitrogen has been substantiated generally by experiments by John G. Seeley at Pennsylvania State College and A. N. Roberts and his associates at Oregon State College. Many treatments have responded quite differently in various parts of the country, however. Deficiencies of boron and magnesium, for instance, appeared to increase scorch in one sand-culture test and and not in another. Results with nitrogen have not always been consistent.

Some of these variable results can perhaps be explained now as a result of cooperative tests made by Stuart at Beltsville and William Skou and D. C. Kiplinger at Ohio State University. One of their treatments gave particularly interesting results. Ammonium sulfate at a rate of 1 ounce in 2 gallons of water was applied every 2 weeks to lilies in the greenhouse. At Columbus the treatment produced the least scorch. The total numbers of scorched leaves were much below those occurring on unfertilized plants. The treatment produced the most scorch at Beltsville, however, and nearly three times as much as occurred on the unfertilized plants.

The average number of scorched leaves per treatment was 32 at Ohio and 188 at Beltsville. What factors could be responsible for such different results? The investigators suggest that perhaps they were due to the differences in soil acidity and water. At Columbus the unfertilized soil had a pH value of 7.3; the water had a pH of 10.5; the soil after treatment with ammonium sulfate had a pH of 6.7. At Beltsville the original soil had a pH of 5.8; the water had an average pH of 7.3; and the soil after treatment with ammonium sulfate had a pH of 3.9. Thus, the soil acidity was markedly different at the two locations. They also reported that in another experiment at Beltsville the least scorch was present on plants grown in quartz sand with a complete nutrient solution plus 25 grams of calcium carbonate per pot. A similar benefit was obtained by adding dolomitic limestone to infertile acid soil.

The effectiveness of lime in preventing scorch of Croft lilies during forcing was investigated by A. N. Roberts, R. E. Stephenson, and S. E. Wadsworth at Oregon State College in 1950 and 1951. Although an application of nitrogen alone completely prevented scorch, the plants were poor and were apparently severely affected with a deficiency of phosphorus or potassium or both. Plants that received a complete fertilizer (nitrogen, phosphorus, potash, and sulfur) and lime at a rate of 8 tons an acre grew very well with only a small amount of scorch. The complete fertilizer without lime resulted in a high rate of scorch, especially in the presence of high amounts of manganese and aluminum. Lime at a rate of 5 tons an acre was less effective than at the 8-ton rate. Also, a high rate of lime overcame the scorching tendency of an unbalance of nitrogen and sulfur in one combination and phosphorus plus potassium in another combination. The lime naturally changed the pH of the soil somewhat; generally the scorch was more severe in the most acid soils. V. A. Clarkson at Oregon State College showed that typical scorch could be induced within about 10 days by the addition of dilute sulfuric acid to the soil.

Such data indicate that the pH might be the determining factor, but some of the additional data from Oregon show that there was no significant difference in scorch on two soils, one with a pH of 6.2 and the other with a pH of 5.0. They raise the question whether the value of the lime is in its neutralizing effect or in its ability to supply calcium to the plant.

In those studies and others it was noticed that plants grown from bulbs produced on different farms varied in the amount of scorch. In the 1950–1951 season, F. P. McWhorter assembled bulbs from 21 growers in California, Oregon, and Washington. The bulbs were forced at Beltsville, Ohio State University, and Oregon State College. Not only was there a different response by different stocks—the relative performance often was different at the three locations. It was evident that the field "history" of the bulbs had a marked effect on the amount of scorch that developed when no fertilizer was used during forcing.

Mr. Roberts and others at Oregon State College in 1948 began studying the possible carry-over effect of fertilizer treatments in the field on forcing performance and scorch development in the greenhouse. Their experiments demonstrated also that the field "history" of the bulbs had a definite bearing on the amount of scorch that developed but that none of the field treatments tested prevented subsequent scorching in the greenhouse. One field treatment containing nitrogen, phosphorus, potassium, sulfur, and manganese actually increased the number of scorched leaves in the greenhouse. A field treatment with nitrogen, potash, potassium, sulfur, and lime was ineffective in reducing scorch, but in that test the lime was used at a rate of 3,480 pounds an acre, which may have been too low. In general, they found that the more complete the nutrition was in the field and the better the growth, the greater was the likelihood that scorch would appear in the greenhouse.

In addition it may be more of a field problem than has been realized heretofore, since F. P. McWhorter and C. J. Anderson in Oregon pointed out in 1951 that "it is probable that a considerable portion of the injury formerly attributed to Botrytis blight may have been due to the physiological disease, scorch."

Our knowledge of the cause and control of scorch is far from complete, although the studies I have reviewed have helped greatly. Apparently scorch follows unbalanced nutrition. The disorder is generally most severe in very acid soils and can be prevented to a great extent in them by heavy applications of calcium and nitrogen. In moderately acid soils it can apparently be alleviated by the use of nitrogen fertilizers alone. But the exact role of nitrogen and calcium and the possible influence of aluminum, manganese, and magnesium are not entirely clear.

Finally, in developing a suitable treatment, commercial factors other than leaf scorch must also be considered—height of the plant, color of leaves, number of flowers. The control program ultimately based on the cause must be one that not only prevents the development of scorch but also one that promotes a good culture.

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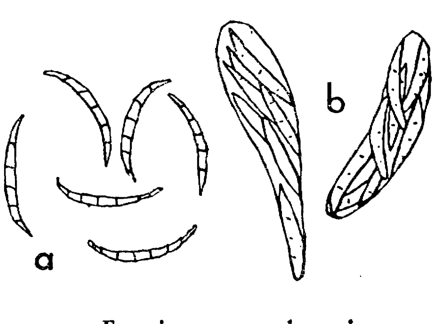

a, Fusarium spores; b, asci.

Narcissus Basal Rot

W. D. McClellan

Considerable concern was felt in England in 1890 about a troublesome rot of narcissus bulbs. The affected plants were stunted, the tips of the leaves turned brown, the flowers developed imperfectly, and the base of the bulb was soft and rotten.

The cause of the rot was not determined. Some investigators blamed unfavorable conditions of soil or climate. One person thought it was due to a fungus. But little effort was made to investigate the trouble until the hot summer of 1911, when large numbers of bulbs rotted during storage in England and the Netherlands.

J. Jacob, in an article in The Garden in 1911, stated that the rot was due to the combined action of heat and *Fusarium bulbigenum*. That fungus, described in 1887, had been found on narcissus bulbs but had not been recognized as the pathogen. Later studies indicated that the fungus was nearly always present with nematodes, which also can cause a rot of daffodils. Johanna Westerdijk in the Netherlands in 1917 distinguished between the nematode disease and the bulb rot due to *Fusarium*.

Before 1924 about 77 million narcissus bulbs were imported annually into the United States, primarily for greenhouse forcing. The Secretary of Agriculture promulgated a quarantine against narcissus because of nematodes and bulb flies, to become effective July 15, 1926. Increasing numbers of bulbs